Test&Measurement

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Space Satellite-Based Optical Amplification Measurements

Introduction

Lack of reliable high-speed internet access in rural regions, due to complicated logistics and the considerable costs involved to extend land-based networks to these areas, has inspired a wave of next-generation applications that will provide greater accessibility and reliability. Making use of "space laser" networks, these revolutionary solutions can relay digital traffic via low Earth orbit (LEO) satellite systems to provide low-latency, high-speed broadband services to communities typically beyond the reach of standard wireless and fiber networks.

Used in traditional optical transmission networks, the amplification technique of employing erbium-doped fiber amplifiers (EDFA) to directly amplify optical signals (without conversion to electrical signals) has now expanded to help boost laser-based signals for orbiting satellite communication networks.

Precision Making

Optical Amplifier Measurements

Optical amplifiers are primarily evaluated with gain and noise figures (NF) via an optical spectrum analyzer (OSA) to measure the optical spectra of input, using Trace A and Trace B respectively. For select applications, a polarization scrambler is placed before the OSA to reduce the effects of the OSA's polarization dependence.

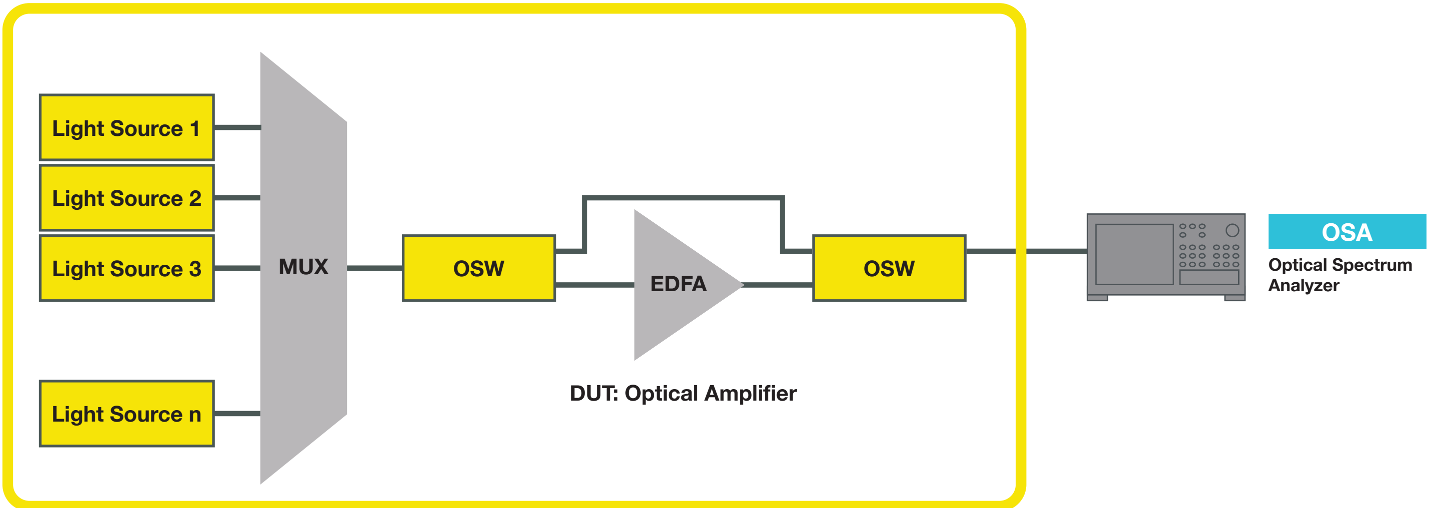

Figure 1. Basic configuration of an optical amplifier measurement.

To obtain accurate gain and NF, it is necessary to exclude the source spontaneous emission (SSE) of the light source being amplified. The gain and NF is then calculated for each channel of the input optical signal. As needed, analysis parameters such as channel detection and amplified spontaneous emission (ASE) level detection should be incorporated to hone results. This can be applied to dense wavelength division multiplexing (DWDM) systems as well.

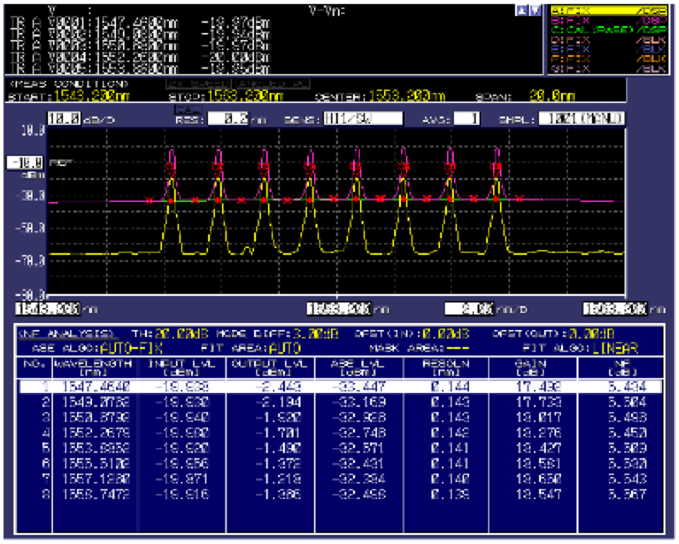

Figure 2. Example EDFA-NF analysis results

Pre-Measurement Steps

To accurately measure the characteristics of an optical amplifier, perform the following steps first:

1 Optical Alignment and Wavelength Calibration

Connect the internal calibration light source out to the optical input port with a single-mode fiber. If an internal calibration light source is not present, calibrate using a single wavelength light source with stable output, such as a DFB-LD.

2 Resolution Calibration

Calibrate the resolution bandwidth of an OSA to the equivalent noise bandwidth (required by IEC standards for optical amplifier measurement) using an external light source. Resolution calibration is recommended due to the filter response of an OSA not typically being rectangular. Because of this, the resolution bandwidth (defined as FWHM) differs slightly from the equivalent noise bandwidth. This step is especially effective when wavelength resolution is 0.05 nm or less (e.g., the difference becomes prominent). With an external light source, use a stabilized single-mode laser light source with an output power of -20 dBm or more, a level stability of 0.1 dBp-p or less, and output line width of 5 MHz or less.

3 Absolute Power Calibration with an Optical Power Meter

Next, calibrate the absolute power reading of the OSA. For the measurement light source, use a single-wavelength light source with stable output, such as DFB-LD and calculate the power correction factor (PCF) using the formula PCF (dB) = P_OPM (dBm) - P_OSA (dBm), where P-OPM is the optical power value on the optical power meter and P-OSA is the spectral peak power value on the OSA.

4 Optical Power Correction (Power Offset)

If optical connectors, splitters, or switches are inserted between the light source and the EDFA input or between the EDFA output and the OSA, researchers must compensate for those losses. After calibrating the absolute power using an optical power meter, double check if there is extra loss that causes errors in the absolute power reading. If additional losses in the input and output paths of EDFA are uncovered, adjust correction values based upon interpolation.

Analysis Parameters

Depending upon EDFA analysis needs there are multiple parameters to consider. The most-commonly used include:

Signal Power

Optical amp gain and NF are obtained after measuring the signal power via the optical amp (as the output light leaves the optical amp). Peak setting is typically employed because a continuous wave (CW) laser light source is used for the EDFA measurements.

Interpolation

Because amplified spontaneous emission (ASE) generated by an optical amplifier is superimposed on the output light, it is important to measure this noise component separately in optical amplifier evaluation. Optical amplifier analysis identifies the ASE component using the curve fitting and interpolation methods.

ASE Algorithm

Use the ASE power calculation algorithm with the defined range of ASE data used for interpolation.

Fitting Algorithm

Optical amplifier analysis identifies the ASE component using the curve fitting and interpolation methods. In addition, the curve fitting method and analysis conditions can be set according to the actual spectrum, so the gain and NF can be obtained accurately.

NF Calculation

Calculating NF involves equations that use the refraction index, speed of light, Planck's constant, gain value, and ASE power. NF formulas from the IEC 61290-10-4:2007 spec are shown in Figure 3.

Analysis result

$NF\ (dB) = P_{ASE\_AMP} - G - 10log[hvB0]$

$P_{ASE\_AMP}\ (dBm),\ G\ (dB),\ v(Hz),\ B_0\ (Hz),\ h(mJs)$

Planck's constant is set to (mJs) according to P_{ASE_AMP}

NF formula (a) (for reference)

$$NF(dB) = 10log(\frac{L_{ASE\_AMP}}{hvB_0G'})$$

NF formula (a) with Shot noise (for reference)

$$NF(dB) = 10log(\frac{L_{ASE\_AMP}}{hvB_0G'} + \frac{1}{G'})$$

The current IEC/JIS standards do not require the shot noise.

Figure 3. NF formulas from the IEC 61290-10-4:2007 spec

Resolution Bandwidth

When selecting the most suitable measurement method that ensures an accurate NF value, always refer to the operations manual and/or supporting technical documents for the OSA in use.

EDFA-NF Analysis Compliance to IEC 61290-10-4:2007

IEC-based calculations for optical amplifier test methods using multichannel parameters (interpolated source subtraction with an OSA) utilize optical power (dBm), optical frequency (Hz), and frequency resolution (Hz) for EDFA analysis.

Conclusion

The general amplifier gain and NF measurement principles are well-established for traditional land-based optical networks that use fiber as the transmission medium. With the push for greater accessibility and more reliable and affordable networking services, EDFA analysis algorithms with optical amplifiers have shown to be directly applicable in free-space applications as well. The tried-and-true technologies and test methods that revolutionized long-haul optical transport networks in decades past are once again pioneering communications with cutting-edge laser-based orbiting satellite networks.

Related Resources

OSA: Characterization of Optical Amplifier Gain and Noise Figure

AQ2200 Applications